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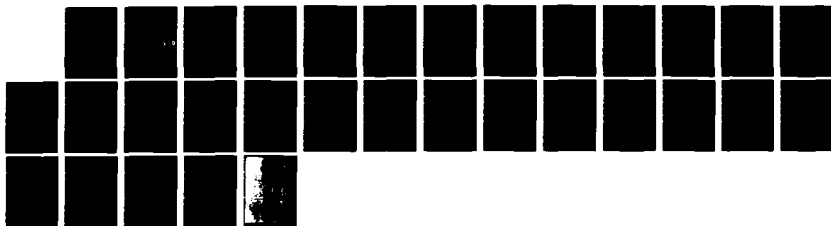
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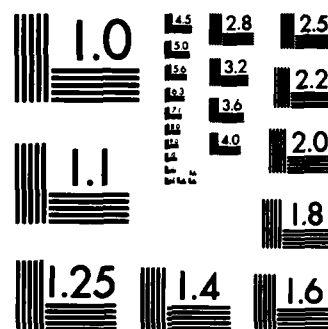
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summer sleep. Heart rates recorded for 9 behavior categories during the summer active period reflected the amount of motor activity associated with the behavior, except for standing and sitting alert which were associated with relatively high heart rates. These probably reflected emotional or other physiological state, factors which are known to affect heart rate independent of motor activity.

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FINAL REPORT

Physiological Studies of Arctic Carnivores

by

Erich H. Follmann

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Fairbanks, Alaska 99701

December 1982

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PHYSIOLOGICAL STUDIES OF ARCTIC CARNIVORES

INTRODUCTION

In cooperation with an Alaska Department of Fish and Game (ADF&G) study of population and habitat use a project was initiated in May, 1977, to study aspects of cold adaptation physiology of grizzly bears (Ursus arctos) on the North Slope of Alaska. This early phase, supported through the Naval Arctic Research Laboratory (NARL) in Barrow, Alaska (ONR Contract N00014-77-C-0162) focused on deep and peripheral body temperature in free-ranging bears during summer and winter. The occurrence of regional heterothermy in bears was anticipated based on measurements from other large mammals, but the degree of difference between the core and the outer shell of the body was unknown, particularly during the winter when bears are in dens and there is a generalized reduction in metabolism and other physiological functions such as heart rate.

In 1979 the project continued with the cooperation of the ADF&G and, in addition, the U.S. Bureau of Land Management (BLM). The BLM was responsible for environmental protection of the National Petroleum Reserve in Alaska (NPRA) which was undergoing extensive geophysical survey, including in the area of the bear study. The cooperation resulted from a common interest in using changes in physiological function to measure the effects of disturbance on bears. This phase involved measurement of heart rate in free-ranging bears to determine baseline heart rates for various activities, including winter denning. Baseline data are included in this report whereas disturbance effects

are being evaluated by the BLM. The latter work was recently presented at a conference (Reynolds et al., 1983).

METHODS

The study area was located in the western Brooks Range on the North Slope of Alaska approximately 320 km south of Barrow. All field work was conducted from Driftwood Camp in the floodplain of the Utukok River.

Bears were drugged with phencyclidine hydrochloride (Sernylan) using darts fired from a helicopter (Reynolds 1980). Bears instrumented with either one temperature transmitter or a heart rate transmitter were processed at the site of capture, whereas those receiving abdominal and subcutaneous temperature transmitters were brought to the Driftwood Camp for surgery. They were returned to the capture site following surgery, to recover from anesthesia. Anesthesia during surgery was maintained with either ether or phencyclidine hydrochloride.

Radio-transmitters with pulse interval modulation for monitoring temperature were calibrated to an accuracy of 0.1°C at the NARL using standard water bath submersion techniques. All transmitters were maintained in a cold sterilant (benzalkonium chloride) until implanted in a bear. Radio-transmitters for monitoring temperature were placed either in the abdomen (Philo et al., 1981) or subcutaneously, lateral to the spine and between the pelvic girdle and last rib. One transmitter was placed subcutaneously in the back of the neck but this location was found to be surgically inferior (Philo et al., 1981). Heart rate transmitters were placed subcutaneously approximately 15 cm lateral to the spine and approximately 10 cm posterior to the scapula to prevent the bear from opening the incision. All surgery was conducted using aseptic techniques.

Most temperature and heart rate data were collected from fixed-wing aircraft using wing-mounted antennas. Radio-collars that were placed on bears at the time of capture were used to locate animals because the range of these units was considerably greater (24+ km) than that of the implants. Once within range the receiver channel was changed to the frequency of the implanted transmitters. Temperature signals were routed through a digital processor (Model TDP-1, Telonics, Mesa, Arizona) which displayed the interpulse period in milliseconds. Temperatures were computed from this data using the regression equation developed from calibration data. Heart rate data were obtained by counting the number of pulses per unit time (minimum 10 seconds) during over-flights. Some temperature and heart rate data were obtained from the ground.

Data were collected throughout the year with the most intensive collection occurring between May and October. Temperature data were collected from May 1977 through June 1979 and heart rate data from June 1979 through September 1981 (Table 1).

Table 1. Grizzly bears instrumented with internal temperature and heart rate transmitters during 1977-1980, Brooks Range, Alaska.

Bear I.D.	Sex	1977		1978		1979		1980	
		Core T°		Core T°	Subcutaneous T°	Heart Rate		Heart Rate	
1081	M	--		--	--	--		X	
1082	M	X		X	X	X		--	
1086	F	X ¹		--	--	X		--	
1096	M	--		X	X	--		--	
1097	F	--		--	--	--		X	
1099	M	--		X	X	--		--	
1105	F	X		X	X	--		--	
1121	F	X		--	--	--		--	

¹ Placed in the back of the neck.

RESULTS

Body Temperature

Mean body temperatures recorded from grizzly bears are summarized in Table 2. During the 1977-78 season only abdominal temperatures were measured except for bear 1086 where the transmitter was situated in a subcutaneous pocket in the back of the neck. This location was deeper than the subcutaneous locations selected for measurements during the following year, and, in fact, the summer and winter temperatures recorded at that location of the body closely paralleled abdominal temperatures recorded from other bears.

During the summer season when bears were active, the mean abdominal temperature recorded was 37.7°C, whereas subcutaneous temperatures averaged 36.3° (Table 2). As expected, when bears were in dens for the winter, body temperatures were lower, that of the abdomen averaging 34.5° and subcutaneous 32.4°. Although body temperatures varied during both summer and winter, in summer with type of activity, the variability was greater when bears were in dens. Body temperature fluctuation while bears are denned indicates that the physiological state of these animals is not static during the denning period. Bears were active to at least some extent in winter which could account for some or all of the temperature fluctuations noted. Activity was determined by temperature data collected from the radio-collars attached to each of the bears. Collar temperatures fluctuated greatly between monitoring flights, sometimes indicating a temperature within 1° of internal body temperature while at other times up to 17.5° cooler than the body.

Table 2. Mean (\pm S.D.) abdominal and subcutaneous body temperatures ($^{\circ}$ C) recorded from grizzly bears during 1977-1979, Brooks Range, Alaska.

Bear I.D.	Summer - Active		Winter - Inactive	
	Abdominal	Subcutaneous	Abdominal	Subcutaneous
<u>1977-78</u>				
1082	37.4 \pm 0.5	---- ¹	33.3 \pm 0.7	-----
1086	-----	37.2 \pm 0.4	-----	33.8 \pm 1.4
1105	37.2 \pm 0.4	-----	33.7 \pm 1.3	-----
1121	37.8 \pm 0.3	-----	33.6 \pm 0.9	-----
<u>1978-79</u>				
1082	38.0 \pm 0.5	36.4 \pm 0.5	36.8 \pm 0.2	33.1 \pm 1.8
1105	38.5 \pm 0.3	37.0 \pm 0.5	35.7 \pm 1.5	33.7 \pm 1.8
1096	37.5 \pm 0.4	35.8 \pm 1.0	34.3 \pm 0.6	29.9 \pm 4.6
1099	37.8 \pm 0.4	36.3 \pm 0.2	36.6 \pm 0.6	-----
Total (N)	37.7 \pm 0.6(110)	36.3 \pm 0.8(54) ²	34.5 \pm 1.5(26)	32.4 \pm 3.2(17) ²

¹ No data collected.

² Does not include Bear 1086.

Temperature variations of the collar reflect whether the transmitter case was situated beneath the chin or was exposed to cooler den temperatures.

Mean temperature differences between abdominal and subcutaneous regions of the body are indicated in Table 3. It is apparent that there was a greater thermal gradient within the body during winter torpor than during summer when bears were active. Also apparent is the greater consistency of temperature differences between the core and shell of the body for bears during summer whereas winter differences ranged between 2.0° and 4.4°, for the five bears monitored.

For all bears, seasonal differences in abdominal temperature were less than for subcutaneous temperatures (Table 4). In one bear (1082) the subcutaneous variation was over twice that of the abdomen and for bear 1096 the seasonal difference recorded for subcutaneous temperature was 5.9°. These data indicate that the temperature of the body shell is considerably more labile than that of the core, an adaptation that would be useful in reducing heat loss during winter torpor.

Heart Rate

A total of 556 individual heart rates were recorded from three wild grizzly bears; 547 of these were collected from two bears, 1086 and 1097. Individual differences were apparent between bears, but group means were calculated to show trends between heart rate and 10 behavior categories involving varying degrees of motor activity (Table 5). To clarify differences in certain of the behavior types shown, grazing entailed extended periods of eating vegetation in a small area, whereas

Table 3. Mean differences (°C) between abdominal and subcutaneous body temperatures of grizzly bears, Brooks Range, Alaska, 1978-1979, using data in Table 2.

Bear I.D.	Summer - Active	Winter - Inactive
1086	1.6	3.7
1105	1.5	2.0
1096	1.7	4.4
1099	1.5	-- ¹
Total	1.6	2.9

¹ No data collected.

Table 4. Mean summer-winter differences of abdominal and subcutaneous body temperatures (°C) of grizzly bears, Brooks Range, Alaska, 1978-1979.

Bear I.D.	Abdominal	Subcutaneous
1082	1.2	3.3
1105	2.8	3.3
1096	3.2	5.9
1099	1.2	-- ¹
Total	2.3	3.9

¹ No data collected during winter.

Table 5. Heart rates (beats/minute) recorded from wild grizzly bears,
Brooks Range, Alaska, 1979-1981.

Behavior	N	Mean	S.D.	Range
In den	303	26	10.1	10-70
Bedded/Sleeping	104	47	10.2	22-75
Nursing	16	55	13.1	32-72
Grazing	16	66	9.8	44-84
Walking	28	68	16.9	32-103
Standing	11	71	14.0	53-92
Sitting Alert	4	74	4.3	70-80
Foraging	35	77	9.1	56-92
Digging	30	82	18.7	52-120
Running	9	102	14.7	92-132

foraging included a combination of walking with head down in search of food and actual feeding. Digging involved excavating for roots and for ground squirrels (Spermophilus parryii). The other behavior categories are self explanatory.

The results illustrate several interesting points regarding heart rate. It is generally accepted that bears reduce their metabolism about 50 percent during periods of winter denning (Folk, 1974; Hock, 1960). Assuming heart rate is an indicator of metabolic activity in bears it is interesting to note that the mean heart rate during winter (26) is approximately half that occurring when bears are asleep during the non-denning period (47). Sleep should approximate resting metabolism in bears during this latter period. A considerable variability is evident (Table 5) with substantial overlap in values for winter denning and sleep during the active season (May - October). Many of the values that overlapped were recorded in May when bears, although in dens, were more active and in some cases had moved about the den area as evidenced from tracks in the snow.

A second point of interest in the data, and one that illustrates the potential problems of using heart rate as an indicator of metabolism, is the influence of emotional or mental state on heart rate. The mean values for standing and sitting alert are about 50 percent higher than heart rates recorded during sleep (Table 5). Although these two behavior categories did not entail any locomotor activity, they were associated with relatively high heart rates. This would suggest that other influences such as emotion or other physiological response to environmental stimuli were acting to promote an elevated heart rate. Vigorous motor activity associated with foraging, digging and especially

running, elevated heart rate as the cardiovascular system responded to increased physical exertion.

The data suggested that mean heart rate increased during the latter stages of winter denning. Heart rates were tabulated by month of collection to verify this trend (Table 6). It is best illustrated by bear 1097 where heart rates averaged 15, 18 and 34 for December, March and May, respectively. Similarly, the variability of recorded heart rates was different between months with the highest occurring in early May while the bear was preparing to leave, or to a limited extent had left, the den. These differences were not quite as apparent for bear 1086 especially due to the relatively high heart rates recorded in December. Some of the variability in December, and perhaps in other seasons, could have resulted from aircraft disturbance as the den was monitored from the air, but the 25 data points do not necessarily reflect this pattern. Heart rate was higher during the first several recordings but two hours later heart rate was about 50 percent of earlier levels. Rather than aircraft disturbance, the data suggest that recordings coincided with some activity adjustment of the bear within the den, as was previously indicated in bears instrumented with implanted temperature sensors and/or radio-collars (see previous section).

The lowest heart rates recorded for bears in winter dens were 10 for bear 1097 and 12 for bear 1086, values consistent with heart rates recorded from captive bears by other workers (Folk, 1967; Folk et al., 1972; Folk et al., 1976). Of interest are the upper ranges of 48 and 70 recorded for bears 1097 and 1086, respectively (Table 6). In both cases, these values occurred during May when, as noted above, bears

Table 6. Heart rates recorded from female grizzly bears 1086 and 1097,
Brooks Range, Alaska, 1979-80 and 1980-81.

	<u>December</u>		<u>Jan./Feb.</u>		<u>March</u>		<u>May</u>	
	1086	1097	1086	1097	1086	1097	1086	1097
N	25	11	72	-- ¹	30	26	129	10
Mean	35	15	20	---	27	18	30	34
S.D.	10.4	2.2	4.9	---	11.2	4.5	9.6	8.5
Range	24-56	10-18	12-47	---	12-53	14-33	20-70	24-48

¹ No data collected.

appeared more physiologically active in the den as the time for emergence approached. However, upper limit values for bear 1086 were high for all months examined. Both bears were females and observations in May at the time of den emergence revealed that bear 1086 had given birth to 2 cubs and bear 1097 to 3 cubs during the previous winter. The influence of parturition and nursing on the heart rate of female bears is unknown, however, it is strongly suspected that these events caused some of the variability found in heart rates during the denning period. The data on nursing during the active season, however, suggests that this behavior has a calming effect on the mother, as evidenced by the relatively reduced heart rates recorded (Table 5).

DISCUSSION

Body Temperature

Regional heterothermy is a commonly accepted condition for homeothermic animals (for example, Gordon, 1977). Since homeotherms are able to regulate thermogenesis and heat loss from the body, it stands to reason that the temperature in various parts of the body could differ depending on physiological state and environmental conditions. For example, in rodents possessing brown fat, the temperature of this tissue is consistently higher than other parts of the body when thermogenesis is activated by cold stress (Cannon et al., 1981). Similarly when an animal must reduce heat loss to the environment peripheral vasoconstriction reduces heat flux by cooling the skin and outer shell of the body. Bears obviously use this strategy in winter dens when they become torpid to reduce heat loss to the cooler den environment.

The lower peripheral body temperatures recorded during all seasons in the grizzly bear in this study indicates that this animal exhibits regional heterothermy at all times. This would be expected in an animal of such large body mass. The core temperature would tend to be far less labile than that of the outer shell, even between seasons, as was found in this study (Table 4). The radio-transmitters placed in the intraperitoneal cavity and in constant contact with the viscera reflected the relative temperature stability in this region as compared to the transmitters which were placed under the skin.

The reduced metabolism during winter which occurs in bears of temperate and more northern regions was certainly manifested in the

animals monitored in this study. Grizzly bears in northern Alaska enter dens usually by mid-October and remain there until April to early May depending on sex and whether an adult female is accompanied by young. The latter usually remain in dens longer than do males and females without young. This extended period in dens to escape the harsh winter of the arctic represents a behavioral adaptation to avoiding thermal stress and food deprivation. To supplement the energy saving efficiency of den habitation in winter, bears also reduce their metabolism, not as drastically as do the true hibernators, but on the order of 50 percent (Folk 1974; Hock 1960). Other physiological changes include reduced heart (discussed in the following section) and respiration rate and reduced body temperature. To withstand the long period of den residency bears put on large quantities of fat to serve as energy stores for metabolism. Interestingly, bears neither urinate, defecate nor eat during this entire period of torpor, a situation again unlike the true hibernators.

It is of interest that the reduction in core body temperature from summer to winter closely agrees with those reported earlier for bears maintained in captivity under simulated natural conditions. An often-stated weakness of some studies on captive animals, particularly of large animals, is that it is difficult to simulate natural conditions. It would appear, based on recorded body temperatures, that the studies of captive bears that took place in Alaska in fact did provide an environment for the animals which allowed them to achieve a physiological state similar to that found in the wild.

Heart Rate

The relationship between mean heart rate and behavior categories representing, in general, an increase in motor activity, is interesting. The behavior categories used would intuitively, in most cases, appear to require different levels of motor activity and this was corroborated by the heart rates recorded (Table 5). The cases of standing and sitting alert being associated with heart rates at the high end of the scale was surprising. One would expect these to be lower, perhaps just above the levels recorded for sleeping. The data strongly suggest the influence of emotional or other physiological factors on heart rate, as is known to occur in man and other animals. The influence of the immediately preceding behavior on heart rate during subsequent standing and sitting could be important, especially in regard to behaviors requiring great exertion, such as, running. For example, Brannon (1983) found mean heart rates of bears drugged with phencyclidine hydrochloride that had run considerable distances prior to recumbency, to be 107, a level slightly above that found in this study for running. These types of influences were not thought to be important for behavior categories of standing and sitting alert in this study. Rather, emotional state seemed to be the most likely explanation.

Heart rates were found to change quite dramatically particularly when a bear became active following rest or in response to a greater level of motor activity. Even in dens during a 1 or 2 minute recording, spurts of a few heart beats sometimes would accelerate to double the preceding rate and then, as quickly, decrease to previous levels. Heart rate is a very labile physiological characteristic and, therefore,

requires that a fairly long (at least 10-15 seconds) duration be recorded to obtain a meaningful average, especially when heart rates are rapidly fluctuating as can occur during bouts of activity.

Some workers have attempted to correlate heart rate with metabolism using oxygen consumption and/or carbon dioxide production to determine the latter (for example, Holter et al., 1976; Lund, 1974). Metabolic data are not available for the grizzly bear otherwise it would be possible to utilize the heart rate information collected in this study in conjunction with the few reports of Alaskan grizzly bear activity budgets (Hechtel, 1983; Stelmock, 1981) to calculate daily and seasonal energy expenditure of wild bears. Such information would provide valuable insight into the energetics and ecology of the bear living in the area of its northernmost distribution.

The mean heart rate of bears recorded during winter denning was about half that recorded for bears sleeping during the active period (Table 5), suggesting a significant reduction during the season when bears are minimizing energy expenditure to survive the long winter period (up to 7 months). The lability of heart rate during both the denning and active periods, as indicated by the ranges (Table 5), suggests that bears in winter dens do become physically, or at least emotionally, active enough to raise heart rates as high as active bears in the summer. As noted earlier, many of these rates were recorded in May when bears were approaching the time of emergence, or had already sojourned short distances from the den but reentered it later. The influence of the presence of young on the physical and emotional status of the adult female is unknown but could have been a factor in this study. I attempted to circumvent this problem by instrumenting male

bears (1081 and 1082), but no winter data were collected from either bear as a result of either equipment failure (bear 1082) or failure to locate the winter den (bear 1081).

SUMMARY

During 1977-81, 8 individual bears were instrumented with radio-transmitters to monitor either body temperature and/or heart rate in the Brooks Range, Alaska.

Body temperatures during summer averaged 37.7° in the abdomen and 36.3° below the skin, whereas in the winter they averaged 34.5° and 32.4° , respectively. Lowered temperature in the winter reflected the reduced metabolism that has been reported for bears during this period. Heart rates were significantly reduced in winter dens compared with summer sleep. Heart rates recorded for 9 behavior categories during the summer active period reflected the amount of motor activity associated with the behavior, except for standing and sitting alert which were associated with relatively high heart rates. These probably reflected emotional or other physiological state, factors which are known to affect heart rate independent of motor activity.

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